Fish Passage Engineering

Hydro Training
U.S. Fish and Wildlife Service
Hadley, MA
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Fish Passage Engineering
Fisheries
Northeast Region
USFWS

Recall that our definition of "fishway" is broad.

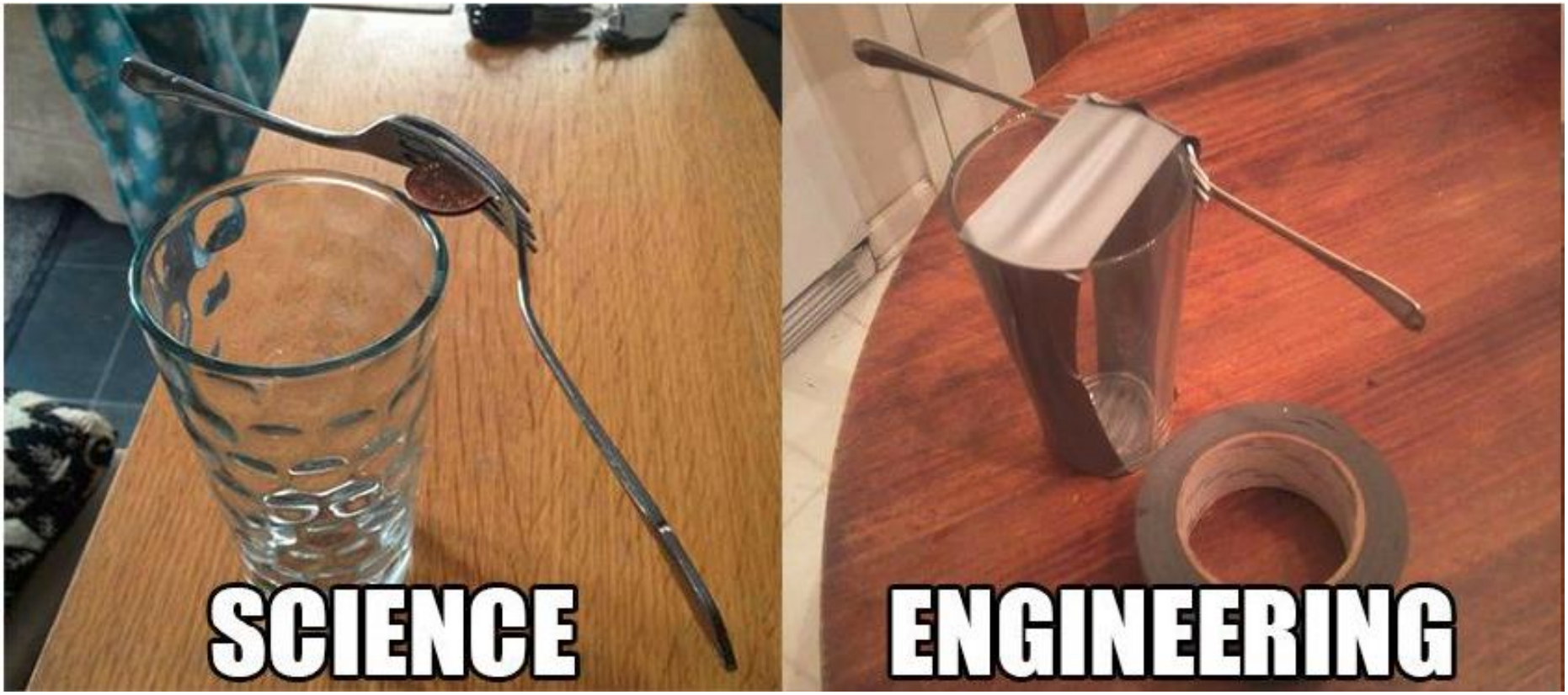
In 1992, Congress provided guidance on what constitutes a fishway in the National Energy Policy Act, Section 1701(b):

"…items which may constitute a "fishway" under section 18 for the **safe** and **timely** upstream and downstream passage of fish shall be limited to **physical structures, facilities, or devices necessary to maintain all life stages of such fish**, and **project operations and measures** related to such structures, facilities, or devices which are necessary to ensure the **effective**ness of such structures, facilities, or devices for such fish."

A fishway can include…

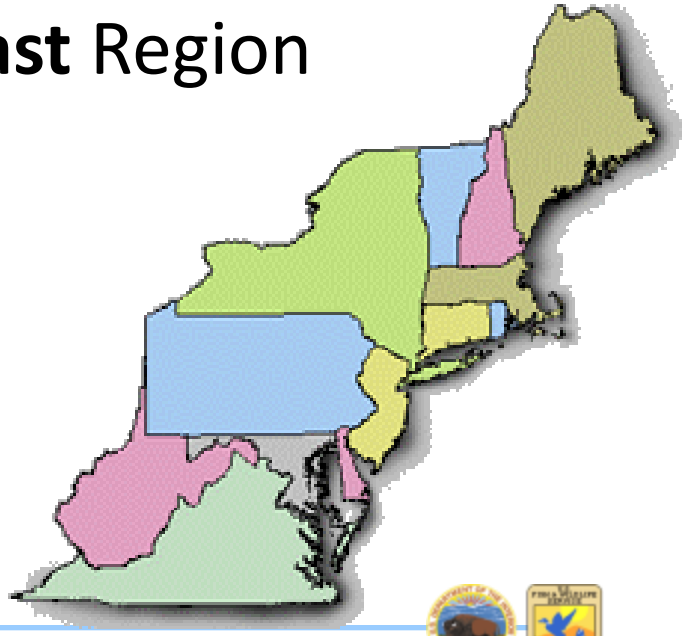
- ✓ **physical structures**
- ✓ **facilities**
- ✓ **devices**
- ✓ **project operations**
- ✓ **measures**

… which involves a great deal of **engineering**.


SCIENCE
ENGINEERING

USFWS R5 Fish Passage Engineering

- **Cadre of engineers** with ___ years of experience in river hydraulics, surface water hydrology, hydropower, and fish passage.
- Organizationally in Fisheries; partially supported by Ecological Services
- Works **throughout the Northeast** Region (and beyond)
- **Supports** FWS biologists, and **consults** with state agencies, tribes, and other stakeholders



How Engineering interacts with the Service and its partners

Hydro

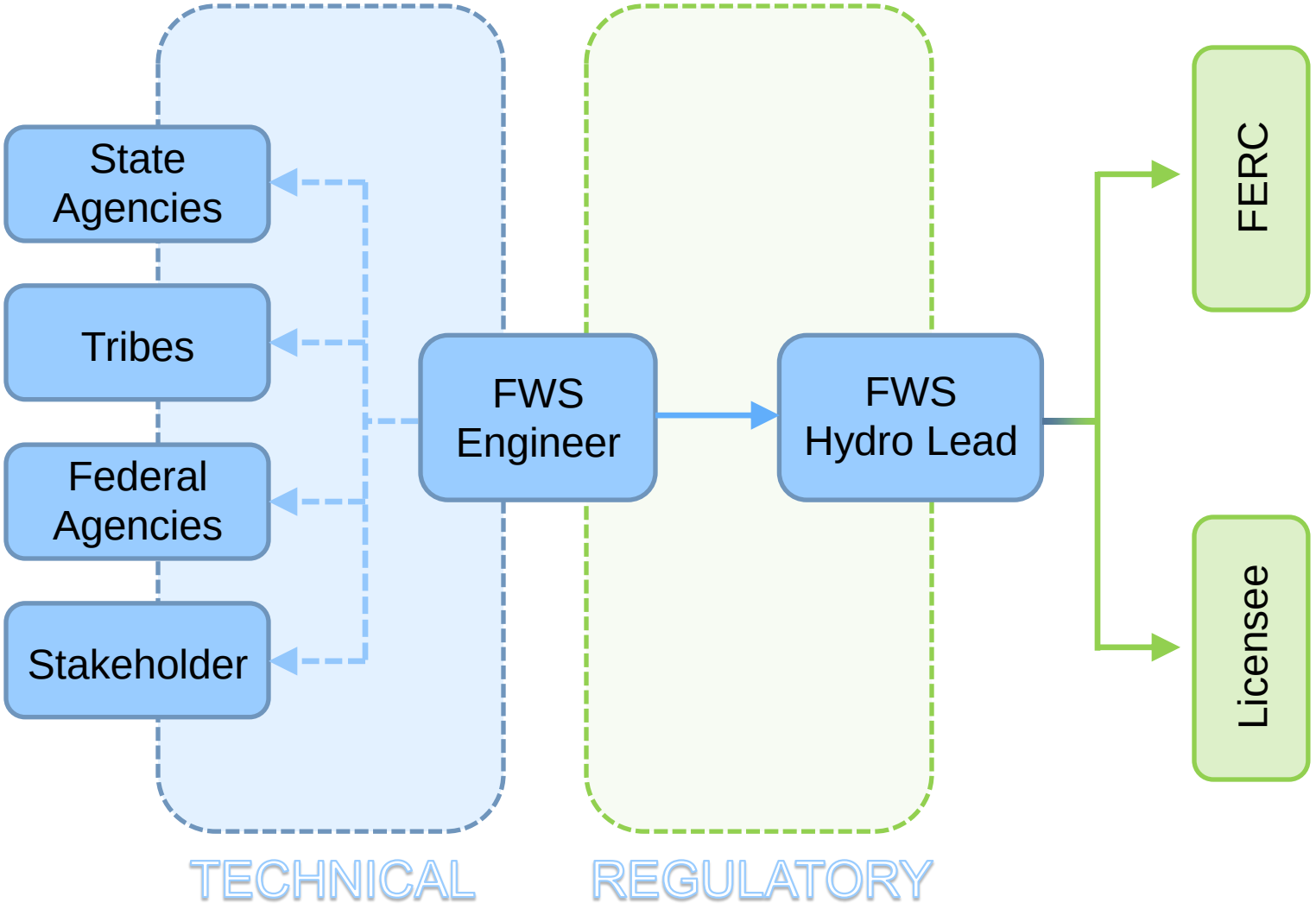
Service Authorities

- Federal Power Act (1921)
- Fish & Wildlife Coordination Act (1934)
- Endangered Species Act (1973)

Non-Hydro

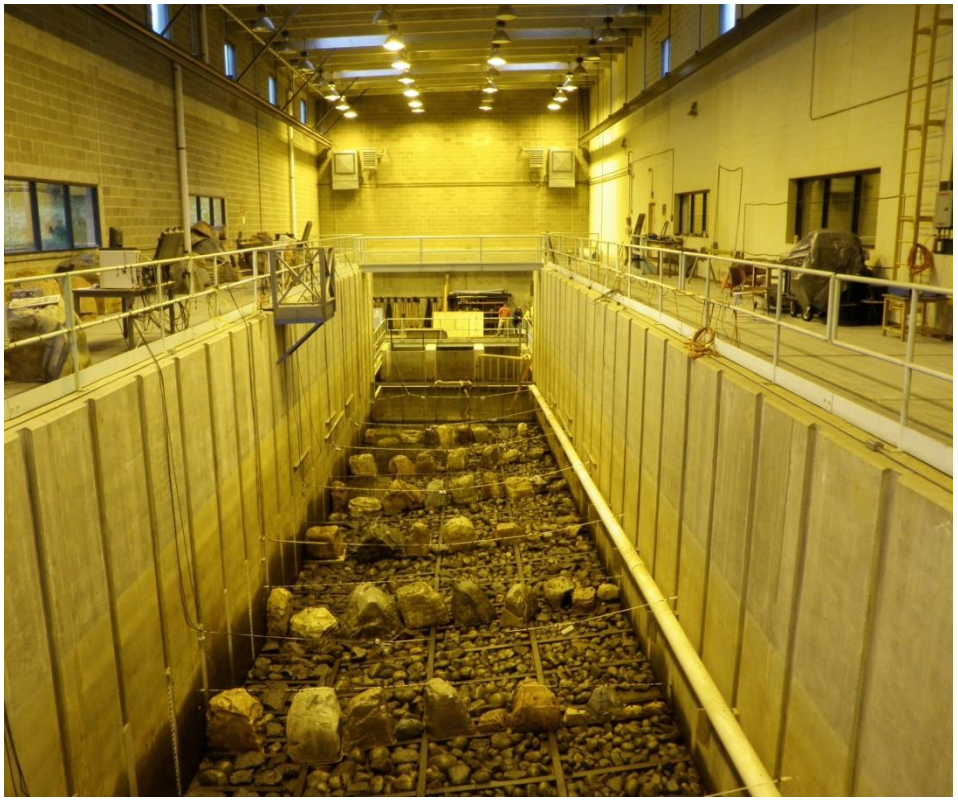
Service Technical & Financial resources

- National Fish Passage Program (1998)
- Partners for Fish and Wildlife (1987)


State Agencies
Tribes
Federal Agencies
Stakeholder
FWS Engineer
FWS Hydro Lead
FERC
Licensee
TECHNICAL
REGULATORY

FWS Fish Passage Engineering Role

- Engineers part of USFWS team **working in coordination** with states, NMFS and other federal agencies
- **Supporting technical support role** in FERC licensing and ESA consultation
- Maintain and develop **USFWS fish passage criteria**
- Fish passage **training**



- Steeppass for river herring (2014)
- Maine DMR, ASF, NOAA &USFWS

Etna Pond, Penobscot drainage

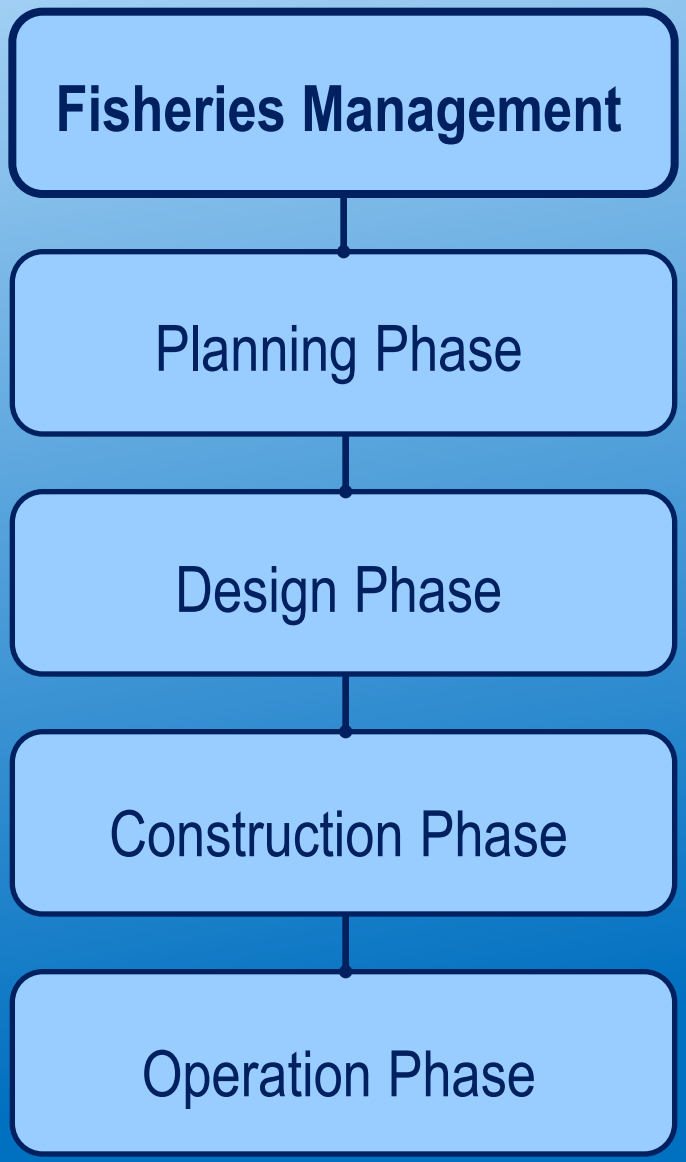
Goal

In the development of upstream and downstream fish passage facilities, our goal is to *maximize performance* and *minimize adverse biological impacts* in a *cost-effective* manner.

Maximize	Minimize	Reduce
Performance	**Injury**	**Construction Costs**
Efficiency	**Stress**	**O&M Costs**
	Delay	

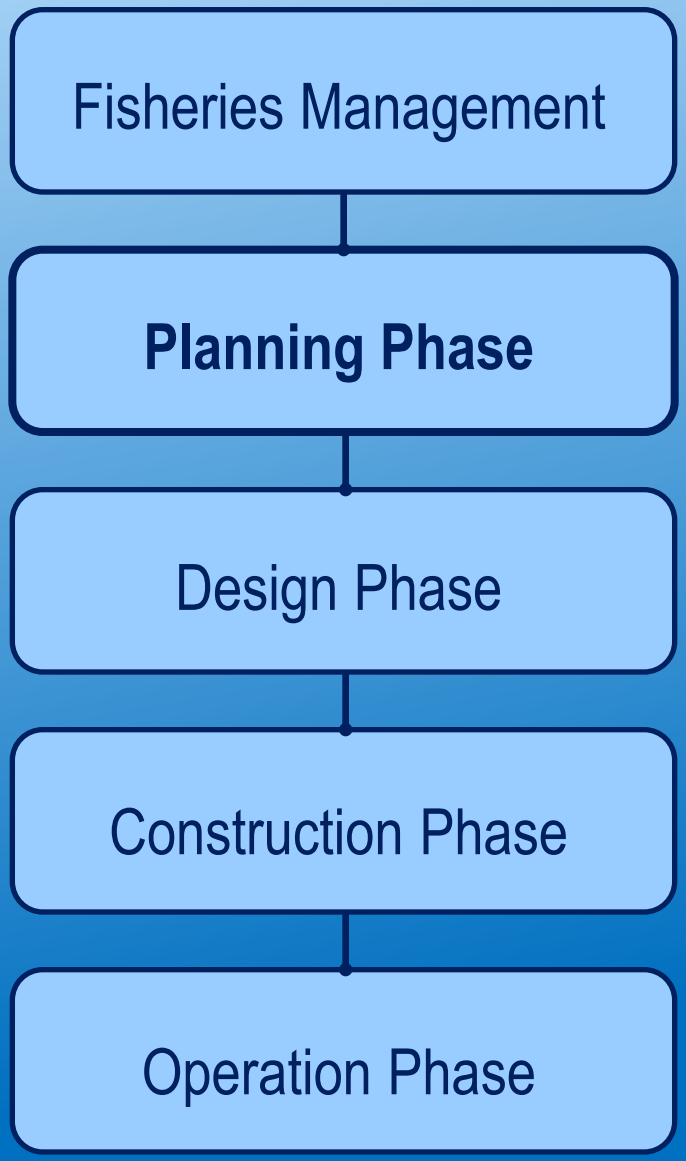
FISH PASSAGE FACILITIES PROJECT SEQUENCE

- Barrier assessment, fishway needs
- Study plan development, review

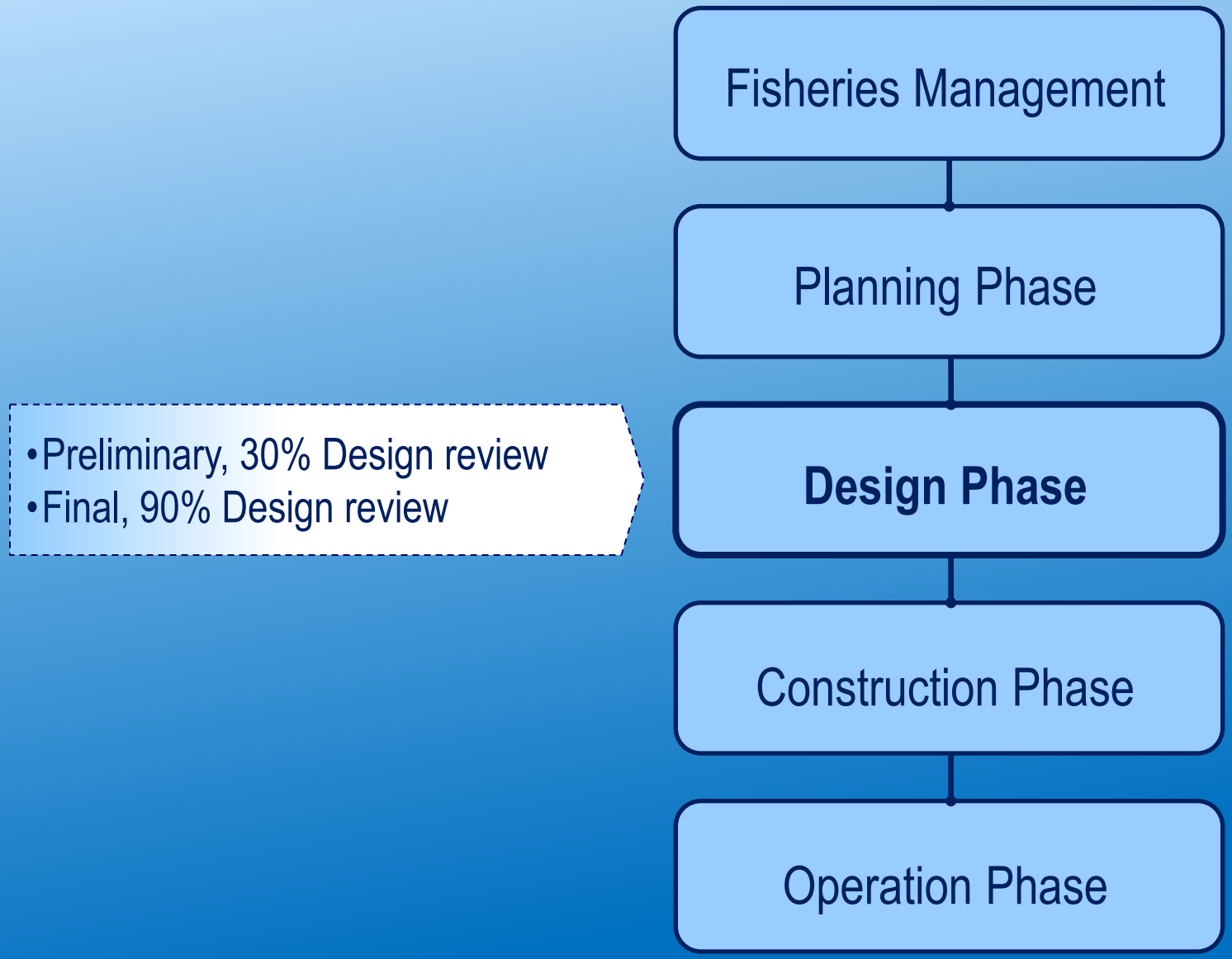


FISH PASSAGE FACILITIES PROJECT SEQUENCE

- Fishway capacity and sizing
- Hydrology, operating range
- Alternatives, conceptual designs



FISH PASSAGE FACILITIES PROJECT SEQUENCE



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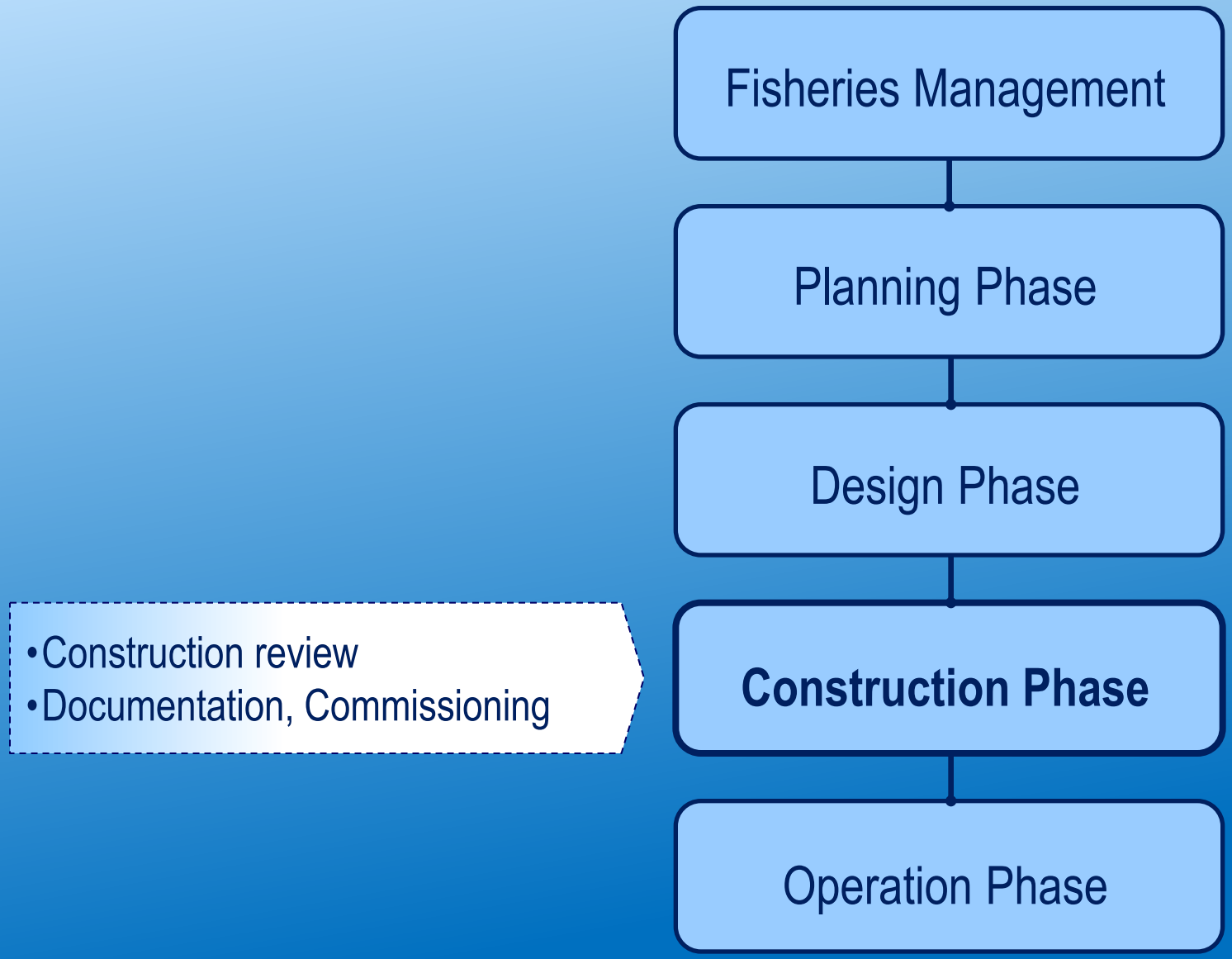

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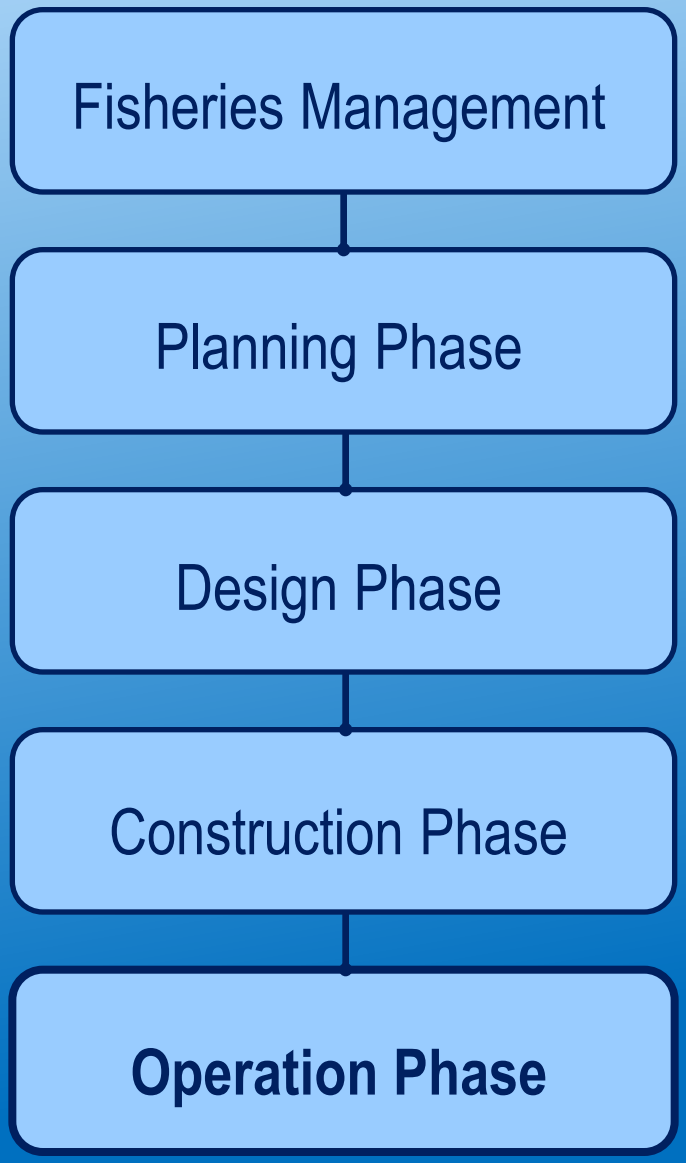


- Annual inspection, stewardship
- Assist w compliance activities
- Technical support

FISH PASSAGE FACILITIES PROJECT SEQUENCE

Fisheries Management

Planning Phase

Design Phase

Construction Phase

Operation Phase

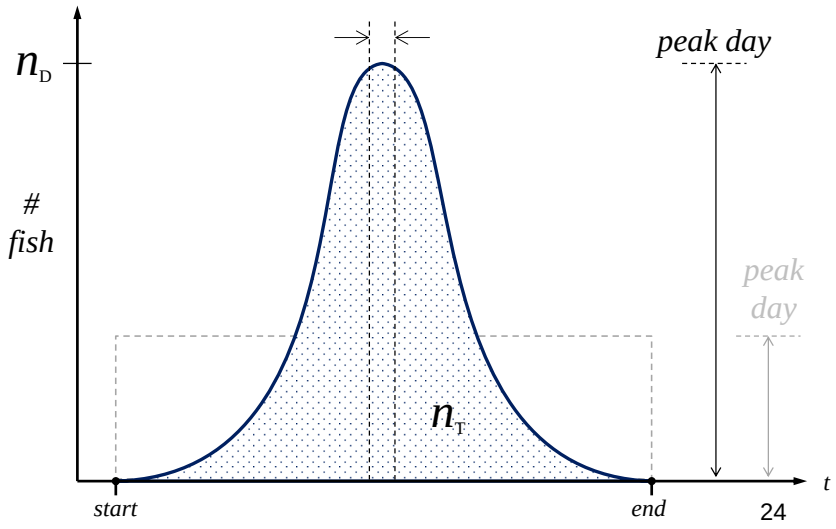
Engineering

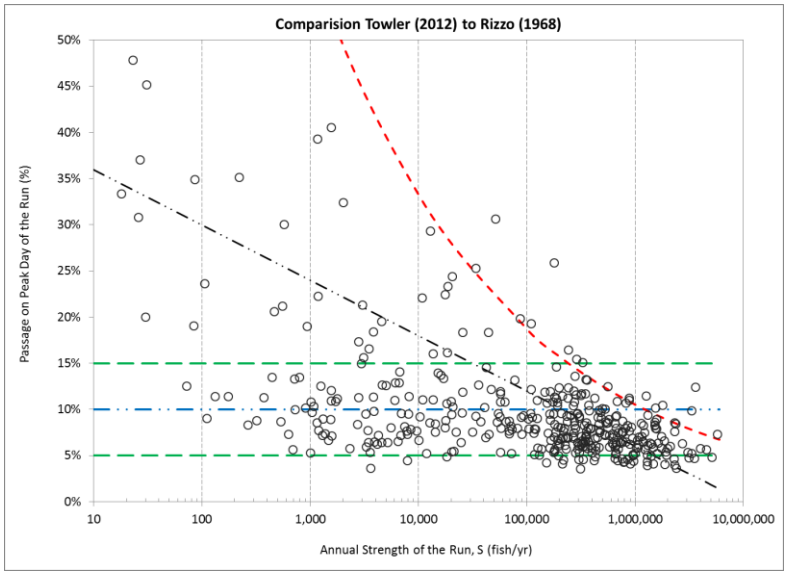
Communication, Coordination, Collaboration!

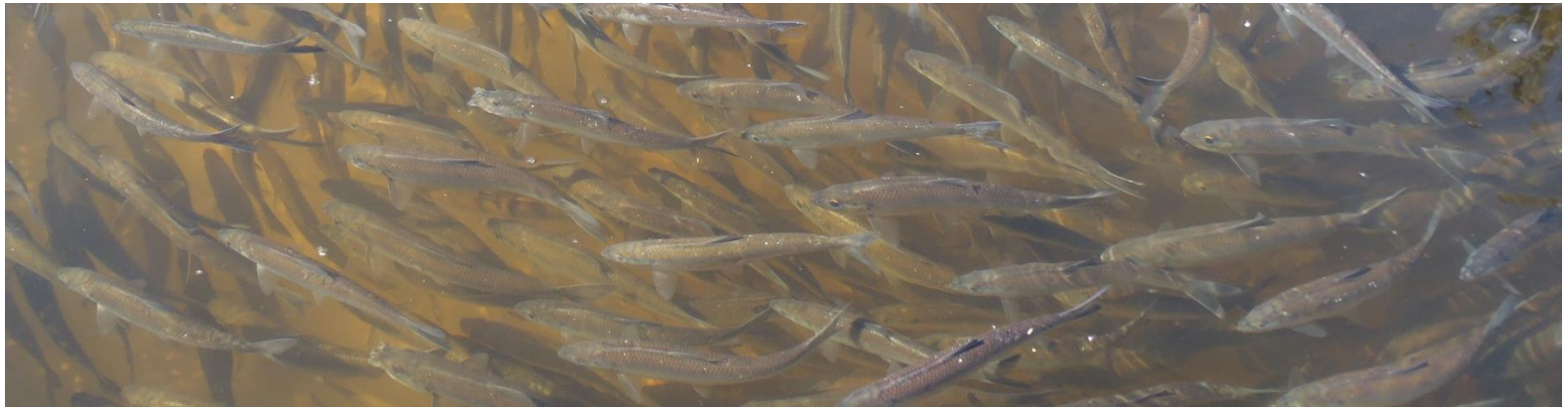
Fish Passage Criteria

- Upstream Passage
  - Design Flows
  - Siting
  - Capacity
  - Attraction Flow
  - Hydraulics
  - Technical Fishways
    - Baffled chutes, Pool-type Ladders, Lifts, Locks
    - AWS, Entrances, Exits, Conveyance
    - Resting and Turning Pools
    - Counting and Trapping

Fishway capacity considerations



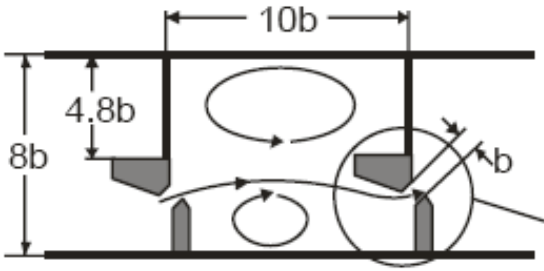




Design #1

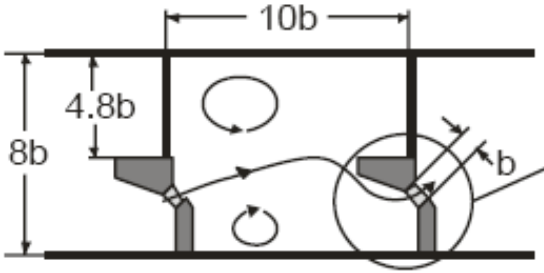
$$Q_* = \frac{Q}{\sqrt{g S_o b_o^{\,5}}}$$

$$u_m = \sqrt{2gh}$$

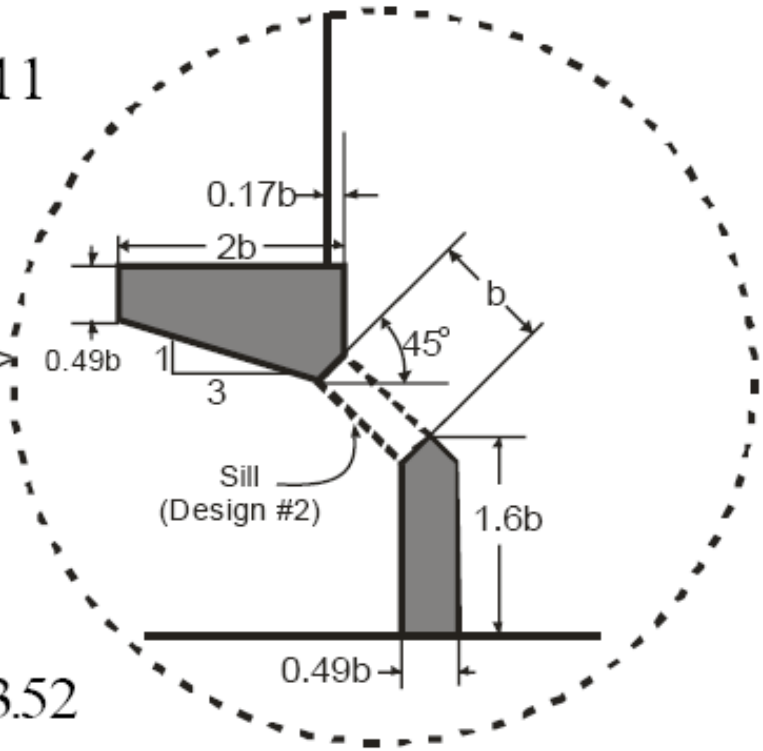


$$Q_* = 3.77(y_o/b_o) - 1.11$$

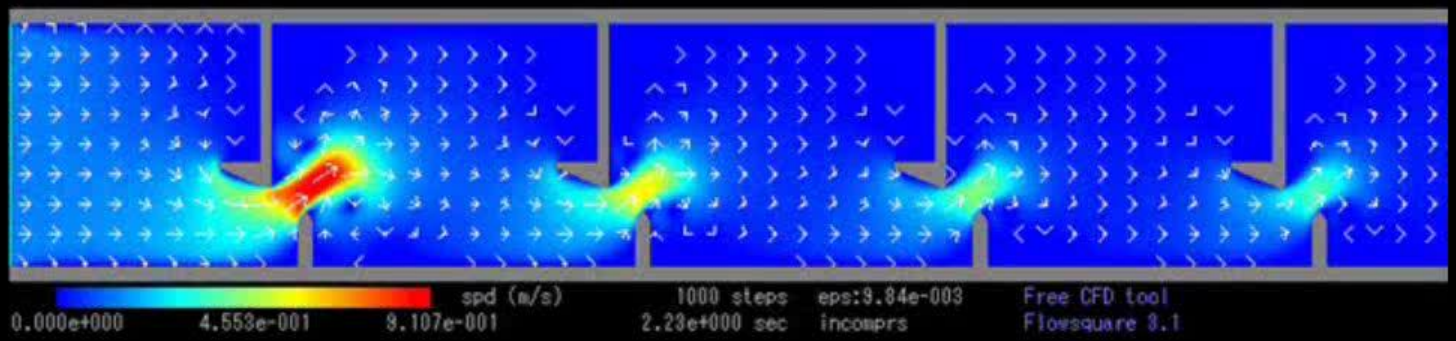
Design #2



$$Q_* = 3.75(y_o/b_o) - 3.52$$



2D CFD Model of a Vertical Slot Fishway
Towler 4/25/2013



Movie tracks convergence of solution. Longitudinal development of flow suggests mass tolerance is too high (i.e.., continuity is not preserved)

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Energy Dissipation Function

Flow Regimes

Mean Channel Velocity, V (ft/s)

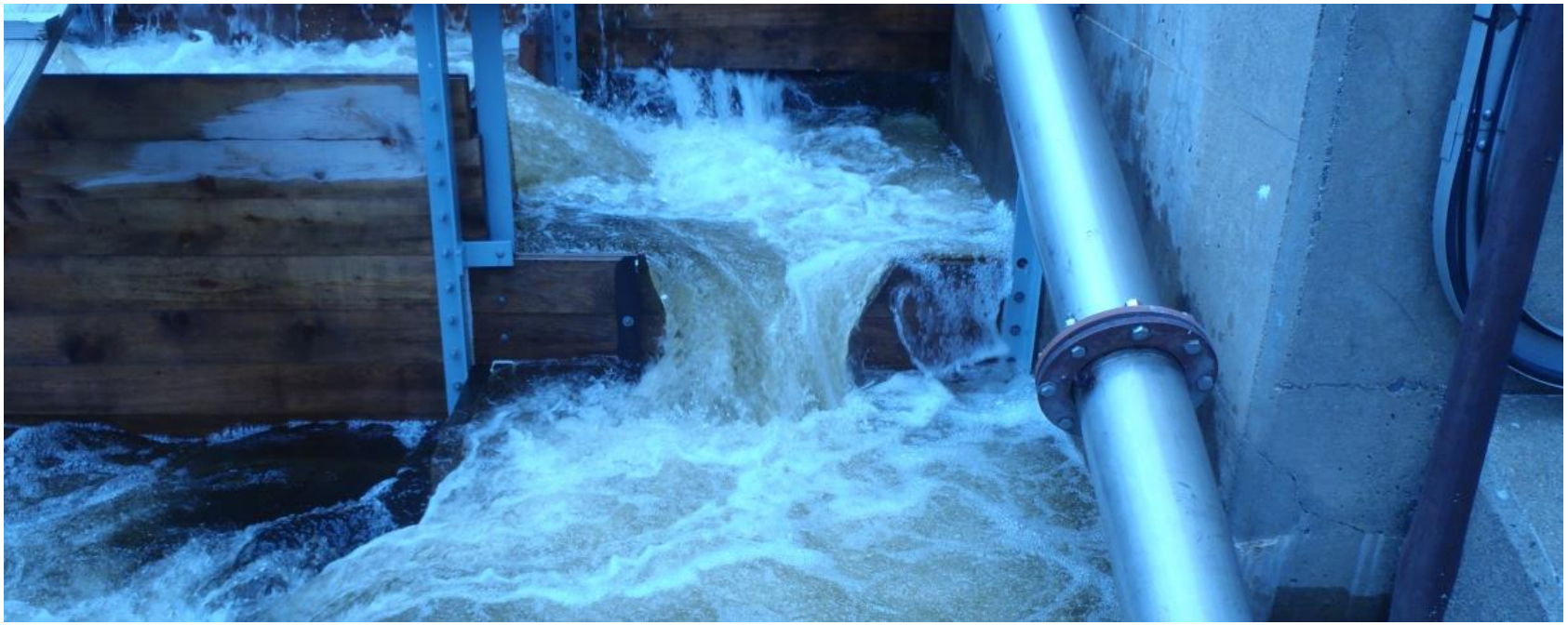
Depth of Water, D (ft)	0	0.0001	0.001	0.01	0.1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	sub-L	sub-L	sub-L	sub-L	sub-L	sub-L	sub-L	sub-L	sub-L	sub-L	sub-L	sub-L	sub-L	sub-L	sub-L	sub-L	sub-L	sub-L	sub-L	sub-L
0.0001	sub-L	sub-L	sub-L	sub-L	super-L	super-L	super-L	super-L	super-L	super-L	super-L	super-L	super-L	super-L	super-L	super-L	super-L	super-L	super-L	super-L
0.001	sub-L	sub-L	sub-L	sub-L	sub-L	super-L	super-L	super-L	super-L	super-L	super-L	super-L	super-L	super-L	super-L	super-L	super-L	super-L	super-L	super-L
0.01	sub-L	sub-L	sub-L	sub-L	sub-L	super-L	super-T	super-T	super-T	super-T	super-T	super-T	super-T	super-T	super-T	super-T	super-T	super-T	super-T	super-T
0.1	sub-L	sub-L	sub-L	sub-L	sub-L	sub-T	super-T	super-T	super-T	super-T	super-T	super-T	super-T	super-T	super-T	super-T	super-T	super-T	super-T	super-T
1	sub-L	sub-L	sub-L	sub-L	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	super-T	super-T	super-T	super-T	super-T	super-T	super-T	super-T	super-T	super-T
2	sub-L	sub-L	sub-L	sub-L	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	super-T	super-T	super-T	super-T	super-T	super-T	super-T
3	sub-L	sub-L	sub-L	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	super-T	super-T	super-T	super-T	super-T	super-T
4	sub-L	sub-L	sub-L	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	super-T	super-T	super-T	super-T
5	sub-L	sub-L	sub-L	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	super-T	super-T	super-T
6	sub-L	sub-L	sub-L	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	super-T	super-T
7	sub-L	sub-L	sub-L	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T
8	sub-L	sub-L	sub-L	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T
9	sub-L	sub-L	sub-L	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T
10	sub-L	sub-L	sub-L	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T	sub-T

sub-L	Subcritical and Laminar Flow
super-L	Supercritical and Laminar Flow
sub-T	Subcritical and Turbulent Flow
super-T	Supercritical and Turbulent Flow

Fish live in a turbulent world!

Fishways and Energy Dissipation

- Various energy dissipation rate recommendations for different species, life stages, and components
- Primary parameter for sizing pools



Energy Dissipation Function (EDF)

$$EDF = \frac{QH\gamma}{\forall_P} \; (ft\text{-}lbf/s/ft^3)$$

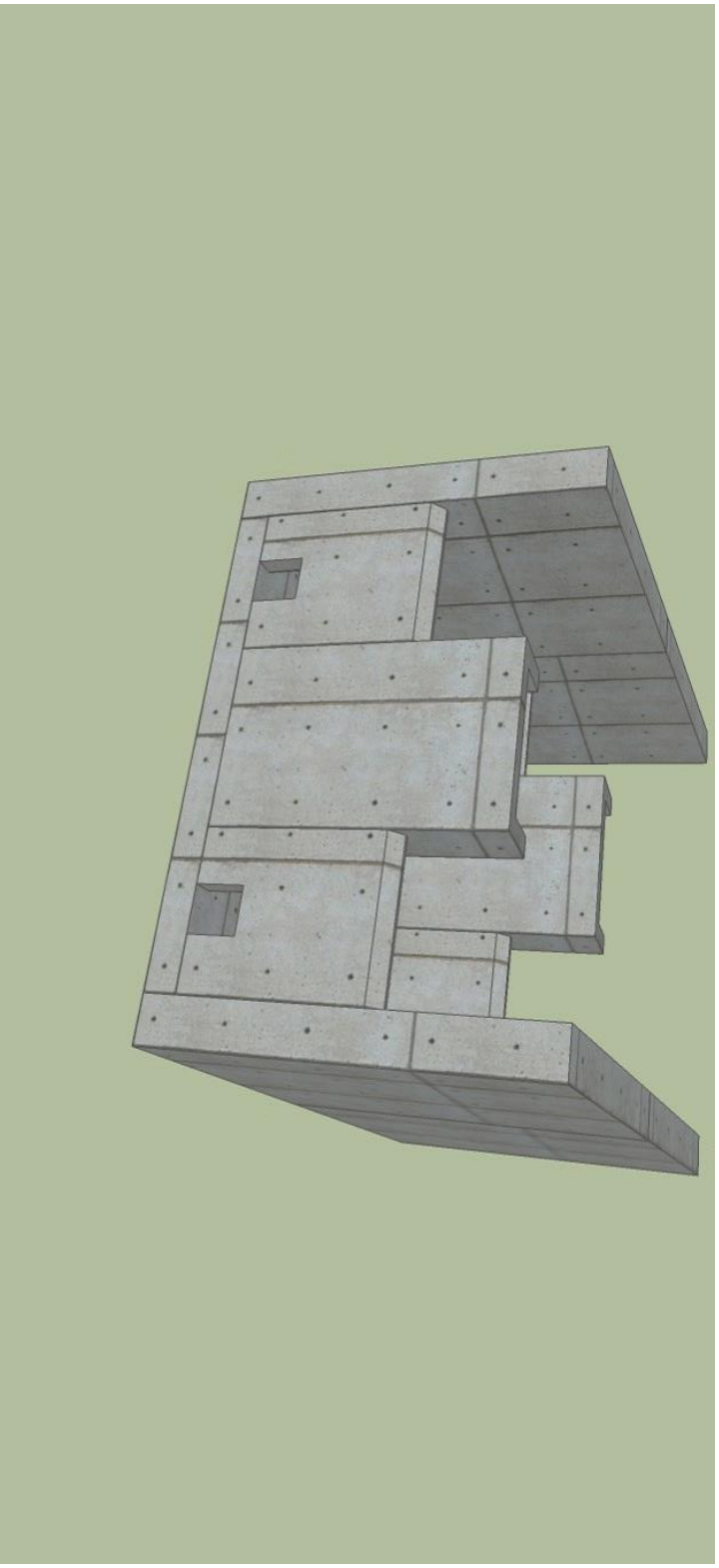
- criterion for turbulence in step-pool technical fishways
- correlates to macro turbulence and aeration

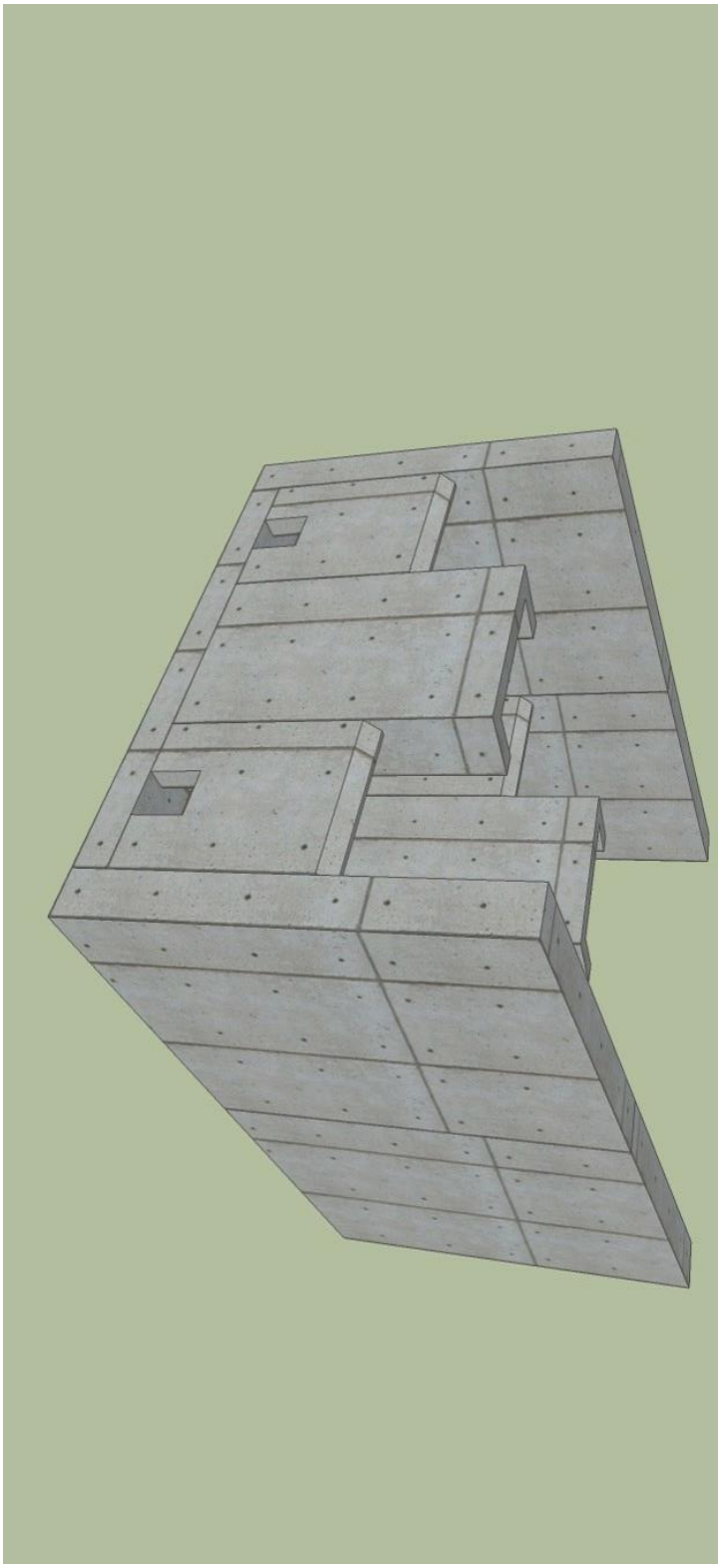
Plunging flow in a pool-and-weir fishway
B. Towler, 2013

Streaming flow in a pool-and-weir fishway
B. Towler, 2013

Streaming

Plunging





increasing depth over weir

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  - **Attraction Flow**
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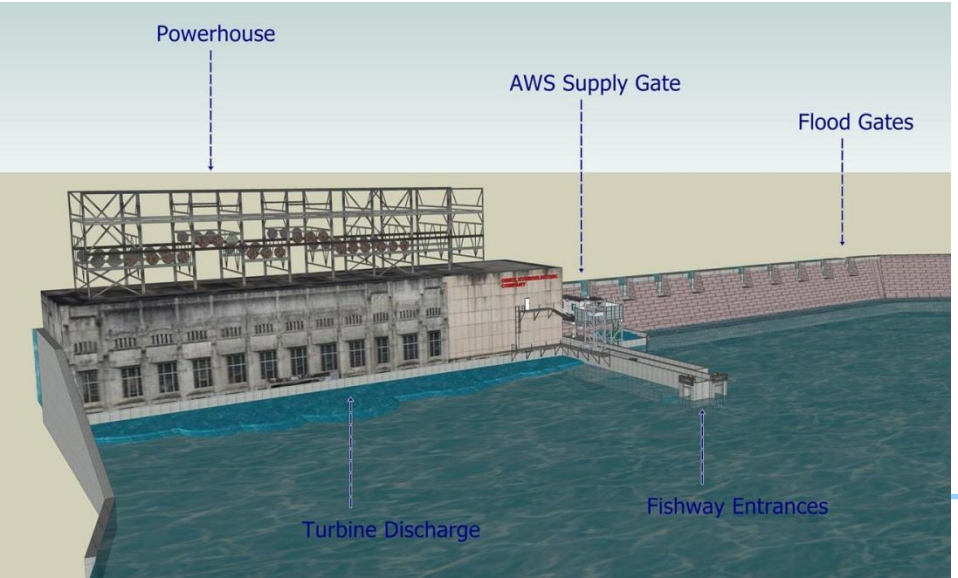
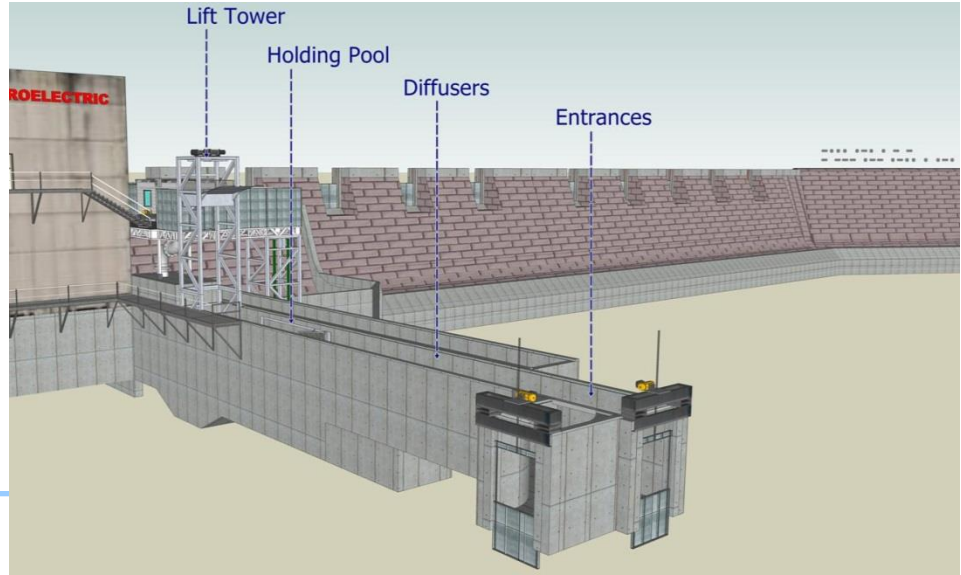
Attraction Flow for U/S Fishways

- PH serves as far-field attraction
- Fishway attraction flow must trigger movement cue in presence of turbine discharge
- 3% to 5% of PH hydraulic capacity





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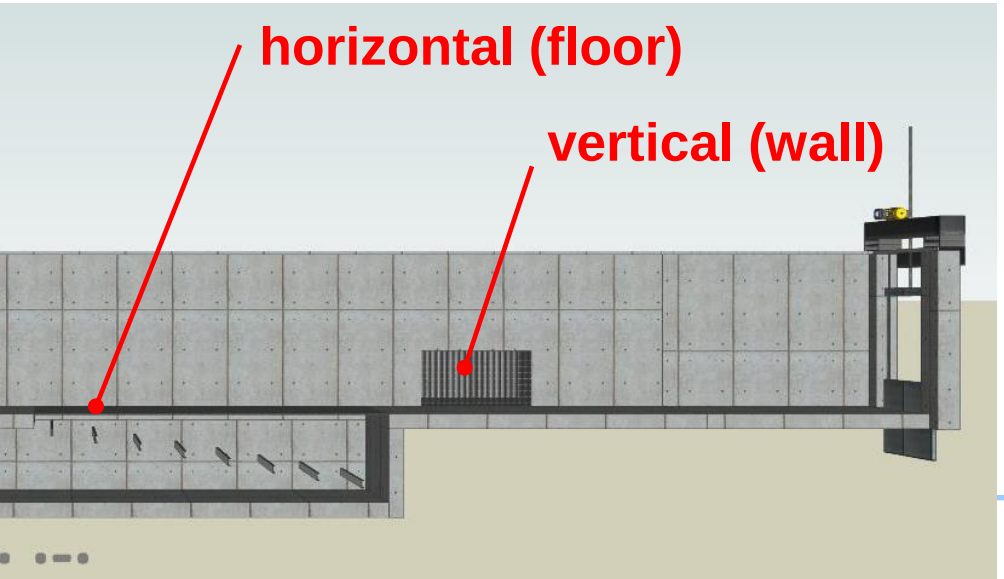
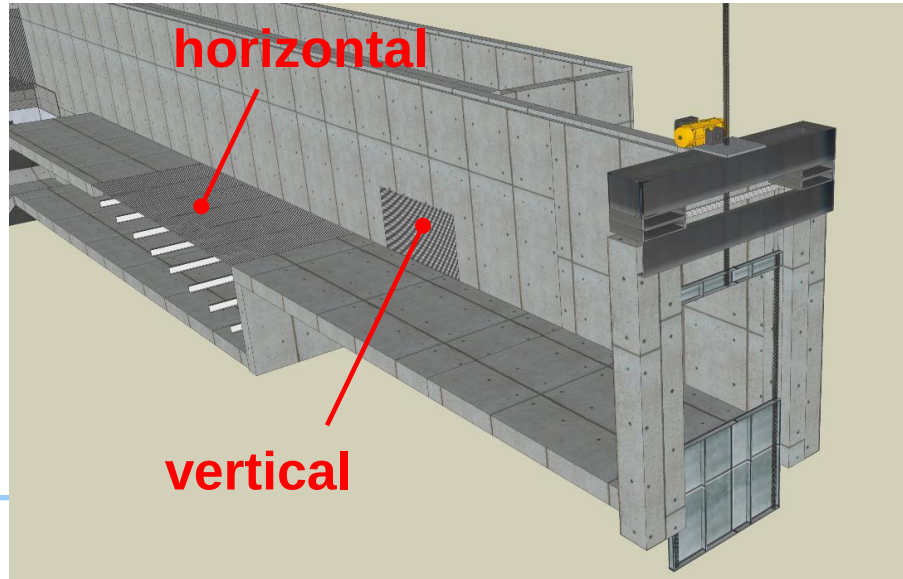
Diffuser Velocities

Velocities Through Diffusers

- Maximum AWS diffuser point-velocity criterion set to prevent confusion in fish
- Vertical/wall diffusers, V ≤ 0.5 ft/s
- Horizontal/floor diffusers, V ≤ 1.0 ft/s





Fish Passage Criteria

- Downstream Passage
  - Exclusion v. Behavior Devices
  - Attraction Flow
  - D/S Guidance
    - Floating guidance systems
    - Angled Bar Racks
    - Louvers
  - Surface and Low Level Bypasses
  - Plunge Pool and Receiving Waters

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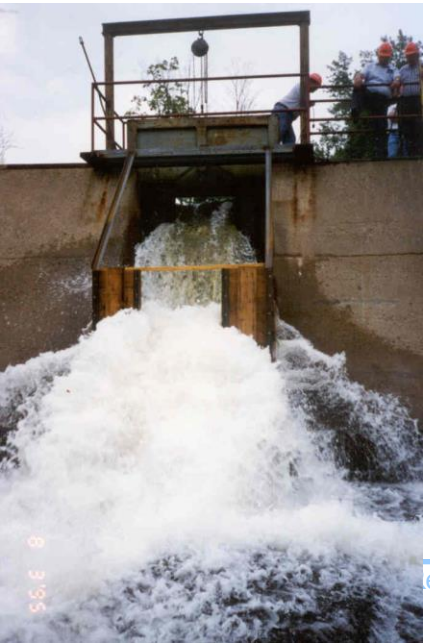
  - Surface and Low Level Bypasses
  - **Plunge Pool** and Receiving Waters

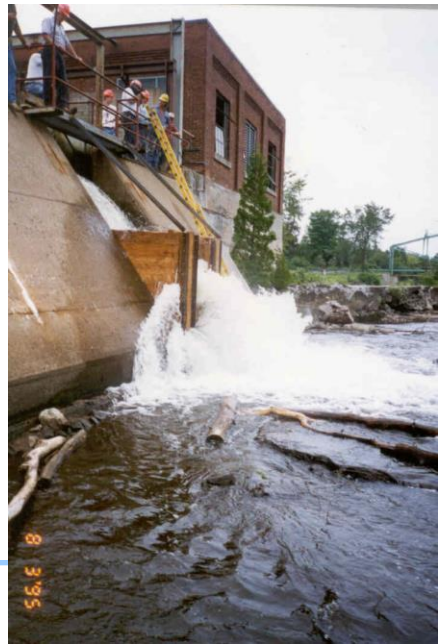
Pool Depth

Plunge Pool Depths

- Adequate depth in receiving waters to minimize injuries to fish exiting D/S bypass outlet
- Plunge pool depth 4 feet or 25% of fall height (whichever is larger)

Yaleville Project FERC No. 9222





Fish Passage Criteria

- Eel Passage
  - Upstream Passes and Traps
  - Downstream Passage
- Nature-Like Fishways
  - Rock Ramps
  - Bypasses
- Other

How Are Criteria Developed?

Service criteria are based on:

- Site-specific studies
- Peer-reviewed research
- Applied research by Agencies
- *Grey literature (FERC Studies)*
- Transferable experience
- Best engineering judgment

Summary

- Anticipate agencies technical input and ***engineering requirements***
- ***Communicate***, ***Coordinate*** and ***Collaborate*** to efficiently achieve fish passage measures that meet Service criteria

"Integrators, not specialists"

- J.F. Orsborn, WSU